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Experimental Study of Bacterial Self-healing Effect on Concrete: A Review

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Abstract—*Concrete is one of the most commonly used material in the world. In concrete mainly cement is used in binder. Eight to 10 percent of the world's total carbon dioxide emissions comes from manufacturing of cement only. In manufacturing of cement, many Gases are released when limestone and clays are heated to high temperatures which causes global climate change. So it is quintessential to develop green concrete by using the supplementary cementitious material in concrete as alternative. On other side, formation of crack is very common phenomenon in any type of concrete structure. Cracking in the surface layers of concrete mainly causes decrease in engineering properties. Cracks are mainly responsible for the transport of gasses and liquids which could contain deleterious substances. When growth of micro cracks reaches to the reinforcement, not only the concrete may get damaged, but also corrosion of reinforcement occurs due to exposure to oxygen and carbon dioxide, and possibly chlorides too. For repairing the cracks developed in the concrete, it needs regular maintenance and special treatments which are being very expansive and not economically sound. Various common soil bacterium like bacillus pasteurii and bacillus subtilis JC3 can be used to improve resistance of cracking in concrete. Overview of development of bacterial concrete using supplementary cementitious material, and its enhanced durability and mechanical characteristics have been described in this paper.*

Keywords*: Bacteria, Bacillus pasteurii, Bacillus subtilis JC3, Green Concrete and Supplementary cementitious materials.*

1. INTRODUCTION

Besides concrete’s versatility in construction, it is known to have many limitations. It is weak in tension, has very limited ductility and not having significant resistance to cracking. Concrete is a major component of the construction Industry as it is relatively cheap, easily available and comparatively convenient to cast. But disadvantage of these material is that it cracks under sustained loading and due to aggressive environmental agents which ultimately reduce the durability of the structure which are built using these materials. If micro cracks grow and reach the reinforcement of concrete, not only the concrete itself may be attacked, but also the reinforcement corroded when it is exposed to water and oxygen, carbon dioxide and chlorides. Micro-cracks are one of the main reason to failure of structure. This process of damage occurs in the early age of structure and also during its life time too.

The major problem of the construction industry is the maintenance cost of the concrete. Natural processes such as weathering, faults, land sliding, earthquake, changes in climate and temperature, have the tendency to create cracks in concrete. Therefore, to counter their effects, it has become mandatory to come up with other ways which will not only help in resisting to formation of cracks but also in improving the quality of concrete.

Application of bacteria can be one of the convenient solution for crack formation in concrete. Other conventional methods like chemical application are effective but it is harmful to human body and environment as well. The main key benefits of bacterial concrete are result is positive and economically sound, no harmful to human body, environment friendly and life of bacterial which are being used as agent is over hundred years.

2. OBJECTIVE OF STUDY

The main objective of this study to review various literatures based on research work carried out on bacterial concrete. This review has been conducted for further study to develop bacterial concrete with influence of supplementary cementitious materials and analyze the engineering properties of concrete.

3. LITERATURE REVIEW

At present literature study, development of bacterial self-healing concrete with various Sustainable cementitious material like GGBS, Silica Fume, and Fly Ash is focused. The main objective is to review the engineering and durability parameter by incorporate with bacteria as a self-healing agent.

Navneet Chahal, Rafat Siddique, Anita Rajor [2] have carried out experiment to evaluate the influence of

Sporoscarcina pasteurii bacteria on the compressive strength and rapid chloride permeability of concrete Made with and without fly ash. In this study they have concluded that Bacteria S. pasteurii plays an effective role in enhancing the compressive strength of fly ash concrete by up to 22% at the age of 28 days. Increase in compressive strength is mainly due to consolidation of the pores inside the fly ash concrete cubes with bacterial induced calcium carbonate precipitation. S. pasteurii has decreased four times reduction in water absorption which could in turn increase durability of concrete structures. Bacterial calcite deposition noticed almost eight times reduction in chloride permeability, hence the life of the concrete structures can be increase. Fig. 1 and Fig. 2 shows result of Compression strength and water absorption test.

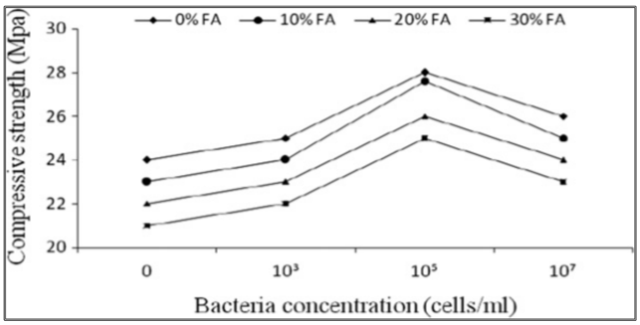

Fig. 1: Effect of bacteria on compressive strength of fly ash concrete at age of 28 days.

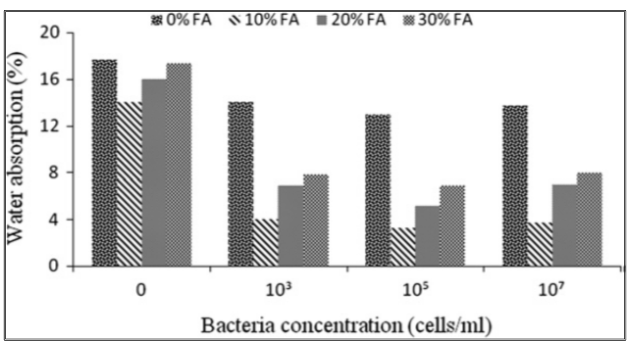

Fig. 2: Effect of bacteria on water absorption of fly ash concrete at age of 7 days.

Sunil pratap reddy, m. V. Seshagiri rao, p. Aparna and ch. Sasikala [4] have conducted experiment on concrete by using the bacteria "Bacillus subtilis strain No.JC3". Calcite formation by Bacillus subtilis JC3 is a laboratory bacterium, which can induced calcite which precipitates on suitable media supplemented with a calcium source. In this study they have concluded that Bacillus subtilis JC3 can be cultured in the laboratory which is proved to be safe for human beings and cost effective. The influence of Bacillus subtilis JC3 bacteria improves the hydrated structure of cement mortar. The compressive strength of cement mortar is optimum with the influence of Bacillus subtilis JC3 bacteria for a cell concentration of 10^5 cells per ml of water. So, bacteria with a cell concentration of 10^5 cells per ml of mixing water is used in the experimental study. The influence of Bacillus subtilis JC3 bacteria enhances the compressive strength of concrete. In ordinary concrete the compressive strength is improved up to 13.93% at age of 28 days by addition of Bacillus subtilis bacteria when compared to controlled concrete. The addition of Bacillus subtilis JC3 bacteria showed significant improvement in the split tensile strength also than the controlled concrete. From the durability tests, the percentage weight loss and percentage strength loss with 5% H_2SO_4 revealed that Bacterial concrete has less weight and strength losses than the controlled concrete. Fig. 3 and Fig. 4 shows result of Compression strength and Acid Attack test.

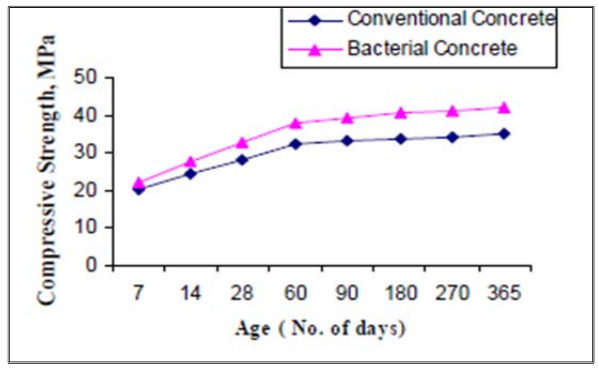

Fig. 3: Effect of bacteria on Compressive Strength with age of concrete.

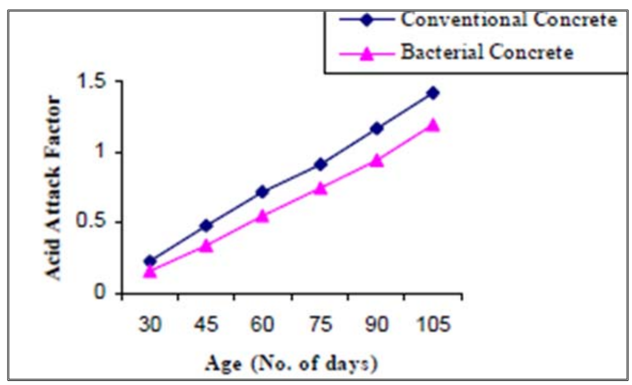

Fig. 4: Effect of bacteria on Acid Attack Factor with age of concrete.

Ravindranatha, N. Kannan, Likhit M. L [3] in this research gives information about the aims at enhancing the strength and the total durability of the concrete used in the present day by addition of bacteria. In this study they have concluded that the microbe proved to be effective in enhancing the properties of the concrete by achieving a very high initial strength increase. The produced calcium carbonate has filled some percentage of void volume thereby making the texture more compact and resistive to crack. When bacterial concrete is fully developed, it may become another alternative to replace ordinary concrete and its hazardous effect on environment. Hence can be used for construction as it is resistant to corrosion as well.

J.Y. Wang, D. Snoeck, S. Van Vlierberghe, W. Verstraete, N. De Belie [1] investigated in this study, bacterial spores were incorporated in from of capsule into hydrogels and then were added into specimens to investigate their healing capacity. The precipitation of $CaCO_3$ by hydrogel-encapsulated spores was tested by Thermo gravimetric analysis. In this study they have concluded that Hydrogel acts as water reservoirs for continuous crack healing process. Carbonate precipitating bacteria can precipitate $CaCO_3$ in hydrogel. Crack of a width 0.5 mm can be completely healed in the specimens with hydrogels. Bacteria based self-healing is very effective solution for development of sustainable concrete. The crack width that can be healed was about 0.5 mm in the specimens it was 0– 0.3 mm with non-bio hydrogels.

Virginie Wiktor, Henk M. Jonkers [6] in this study researchers found that Crack formation is a common phenomenon in concrete structures. Micro crack formation decreases structural properties of constructions, increased permeability due to micro cracks may reduce the durability of concrete structures due to risk of ingress of aggressive substances. In order to increase the often observed autogenously crack-healing ability of concrete, various bacteria can be used as healing agents and applied in the concrete matrix. The aim of this study was to quantify the crack-healing ability of a specific and novel two-component bacterial self-healing agent embedded in porous applied clay particles, which act as particles of reservoir and replace part of regular concrete aggregates. They have found that the microbial enhanced crack-healing ability is positive due to combined direct and indirect calcium carbonate formation: (i) direct $CaCO_3$ precipitation through transformation of calcium lactate and (ii) indirect formation due to reaction of metabolically produced CO_2 molecules with $Ca(OH)_2$ minerals in the concrete matrix guiding to additional $CaCO_3$ precipitation. Active bacteria consume oxygen, the healing agent may act as an oxygen diffusion obstacle protecting the steel reinforcement against corrosion.

Varenyam Achal, Abhijeet Mukerjee 1, M. Sudhakara Reddy [5] have investigated that Microbial induced calcium carbonate precipitation is a naturally occurring biological process by bacteria as agent that has various applications in different kind of building materials. In the present study the role of bacteria Bacillus sp. on the engineering properties and healing of cracks in cementitious structures were studied. Bio cement induced by using Bacillus sp. lead to more than 45% decrease the porosity of mortar specimens, while chloride permeability of concrete changed from moderate to low as indicated by rapid chloride permeability test. They have found that effectiveness of bacteria induced calcium carbonate precipitation has been demonstrated in healing of cracks in building materials. The crack healing process of bacteria improves the strength and durability of the building structures. It results in the decrease in water and chloride ion permeability. It also binds the sand particles together and acts as cement.

4. MAJOR OUTCOME

The various researches conducted on bacterial self-healing Concrete as high strength concrete the following outcomes measured are as follows:

- Bacteria S. pasteurii plays an effective role in improve the compressive strength of fly ash concrete by up to 20% at the age of 28 days.
- In controlled concrete the compressive strength is enhanced up to 12.93% at 28 days by application of Bacillus subtilis bacteria when compared to controlled concrete.
- The microbe proved to be efficient in improving the properties of the concrete by achieving a very high initial strength increase and thus we can conclude that the produced calcium carbonate has filled significant percentage of void volume thereby making the texture more compact and resistive to cracking.
- The increase in compressive strength is mainly due to consolidation of the pores inside the fly ash concrete cubes with bacterial induced calcium carbonate precipitation. S. pasteurii causes four times reduction in water absorption which could in turn improved durability of concrete structures.
- Crack of a width 0.5 mm can be fully healed in the specimens when hydrogels embedded.
- The maximum crack width that can be healed was about 0.5 mm in the specimens, it was 0– 0.3 mm in the ones without hydrogels.
- The healing agent bacteria may act as an oxygen diffusion barrier protecting the steel reinforcement against corrosion thus it’s enhance the durability of the structure.

5. CONCLUSION

Many researchers have found the benefits of bacterial concrete which includes the enhancement of compressive strength, decrease in permeability and reinforced corrosion in construction materials. This innovative concrete technology will soon provide the basis for an alternative and high performance structures that will be cost effective and environmentally safe but, more work is required to improve the feasibility of this technology from both a practical and economical point of view. This novel application of bacteria can be further extended for various types of concretes like high volume fly ash concrete, self-compacting concrete and reactive powder concrete which are recent advances in concrete technology.

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